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Selection of Appropriate Species of Plants for Indoor Vertical Garden

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Abstract Thirty-two species of ornamental plants, *Asplenium thunbergii*, *Alocasia sanderiana*, *Anthurium crystallinum*, *Anthurium andraeanum*, *Aeschynanthus radicans*, *Chlorophytum bichetii*, *Cercestis mirabilis*, *Caladium lindenii*, *Calathea makoyana*, *Dracaena surculosa*, *Echinodosus cordifolius*, *Geogenanthus undatus*, *Monstera obliqua*, *Monstera delicosa*, *Monstera karsteniana*, *Neoregelia carolinae*, *Nephrolepsis biserrata*, *Nephrolepis exaltata*, *Ophiopogon jaburan*, *Ophiopgon japonicas*, *Philodendron erubescens*, *Phyllanthus myrtifolius*, *Philodendron moonlight*, *Philodendron cordatum*, *Philodendron moonshine*, *Philodendron Imperial* Red, *Peperomia caperata*, *Pseudorhipsalis ramulosa*, *Scindapsus pictus*, *Selaginella wallichii*, *Syngonium podophyllum* and *Syngonium podophyllum*, were planted in vertical garden. They were gathering data; survival rates, growth rates, beautifulness rates and light intensity. Analysis data by calculated the percentages of survival rates, average growth rates, average beautifulness rates and light intensity. The duration of experiment was 8 months. The result showed that 12 species of ornamental plants were most appropriated to vertical garden. The selected plants was 80-100% of survival rate, the score of growth rates and beautifulness rates more than 4 scores. They were *Caladium lindenii*, *Philodendron moonlight*, *Syngonium podophyllum*, *Alocasia sanderiana*, *Philodendron erubescens*, *Scindapsus pictus*, *Cercestis mirabilis*, *Anthurium crystallinum*, *Dracaena surculosa*, *Monstera delicosa*, *Philodendron cordatum* and *Monstera karsteniana*. Light intensity level that appropriate for growth rates was 1600 LUX.

Keywords: ornamental plant, vertical garden

Introduction

At present the vertical garden has attacked attention to people from many country, include Thailand, due to environmental awareness that urge people try to live in green place but the situation wasn't suitable to this because most urban people live in small area such as condominium or commercial building (Phasini, 2013). The idea of vertical garden was created by Patrick Blanc, French botanist who tried to make relationship between building and plant that would make beautifulness and shadow for building (Pasinee, 2014). There weren't abundant studying about vertical

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garden in Thailand which concern about how to select the ornamental plant that suit with the type of planting and environment for longer living, beautifulness and easy for look after. Beside this the intensity of light was very important for vertical garden. If the intensity of light not enough for plant, we have to enhance for it. The automatic irrigation systems or hydroponic which use together for apply fertilizer have to suitable for vertical garden in type of felt system. The purpose of this study was to find out the plants which appropriate to culture in vertical garden inside building and by using hydroponic nutrient solution in field system, which easy to look after and longer living.

The objective was to select the appropriated ornamental plants for culture in vertical garden by using hydroponic nutrient solution in field system.

Materials and Methods

Equipments

1. The structure of vertical building was made from iron which adheres to the wall of building and left the distance about 10cm.
2. The curtain was made by PVC and knitted to be plate (similar to the sack of fertilizer) and dovetailed with sponge (for keeping the moisture) and stitched to be squares in the size of 10cm x 12cm. Then slit the holes likely the pockets. The size of plate was 3m x 3.5m.
3. Nutrient solution's tank.
4. The media for planting was spathe of coconut, coir, chaff and rice-husk ash.
5. The formula of salad's hydroponic fertilizer
6. The measurement equipment
   - Digital Lux Meter (Lx1010BS)
   - EC Meter (Bluelab, EC 0.2-3.6)
   - pH adjustment solution
   - Camera (Cannon 60D)
   - Notepaper
7. Kind of tree

   The plants were 32 species that included 5 properties as beautiful shape, beautiful color, and endurance, small and have abilities to growth indoor faintly. There were *Asplenium thunbergii*, *Alocasia sanderiana*, *Anthurium crystallinum*, *Anthurium andraeanum*, *Aeschynanthus radicans*, *Chlorophytum bichetii*, *Cercestis mirabilis*, *Caladium lindenii*, *Calathea makoyana*, *Dracaena surculosa*, *Echinodosus cordifolius*, *Geogenanthus undatus*, *Monstera obliqua*, *Monstera delicosa*, *Monstera*

karsteniana, *Neoregelia carolinae*, *Nephrolepsis biserrata*, *Nephrolepis exaltata*, *Ophiopogon jaburan*, *Ophiopgon japonicas*, *Philodendron erubescens*, *Phyllanthus myrtifolius*, *Philodendron moonlight*, *Philodendron cordatum*, *Philodendron moonshine*, *Philodendron Imperial*, *Peperomia caperata*, *Pseudorhipsalis ramulosa*, *Scindapsus pictus*, *Selaginella wallichii*, *Syngonium podophyllum* and *Syngonium podophyllum*.

Methodology

1. Prepared all 32 species of ornamental plants
2. Transfer the plant for growing in planting pocket which contain with the media and arranged suit with the planning.
3. Prepared 4 LED spot light with 50W, were set on the ceiling far from plant 1.5m. The timer was arranged for turn on spot light from 7am-6.30pm which turn on 1 hour for 8 times per day and during each time had to stop 30 minutes.
4. The data collection was done 16 times for 8 months. The data collection was 1) The intensity of light 2) Survival rate 3) Growing rate 4) Beautiful rate
   4.1 The light intensity measurement had divided the plate into 12 points and collected data every month and measured 3 times as 9am, 12.00pm and 4pm.
   4.2 Survival rate was calculated by

$$\text{Survival rate (\%)} = \frac{\text{Number of survival plants x 100}}{\text{Total of plants}}$$

   4.3 Growing rates were rating by 5 people every month, by use index of Pichsinee, 2013:
   0 No growth (died)
   1 Low growth
   2 Rather low growth
   3 Fairly growth
   4 Good growth
   5 Excellent growth
   4.4 Beautiful rate was rating by 5 people every month, by use index of Pichsinee, 2013:
   0 No beautifulness (died)
   1 Low beautifulness
   2 Rather low beautifulness
   3 Fairly beautifulness
   4 Good beautifulness
   5 Excellent beautifulness

5. The analysis of data
   5.1 Calculated the percentage survival rates
   5.2 Calculated averages of growth rate
   5.3 Calculated average of beautiful score
   5.4 The averages of light intensity 12 points which divided into 3 periods which was morning (9am), afternoon (12.00pm) and evening (4pm).

Results

Light intensity

For the light intensity, the result showed that all 12 points of light intensity showed the different result. Point 1, 2 and 3 got 1,600 LUX, point 4, 5 and 6 got 1,350LUX, point 7, 8 and 9 got 1,250LUX and point 10, 11 and 12 got 1,000LUX (Fig.1).

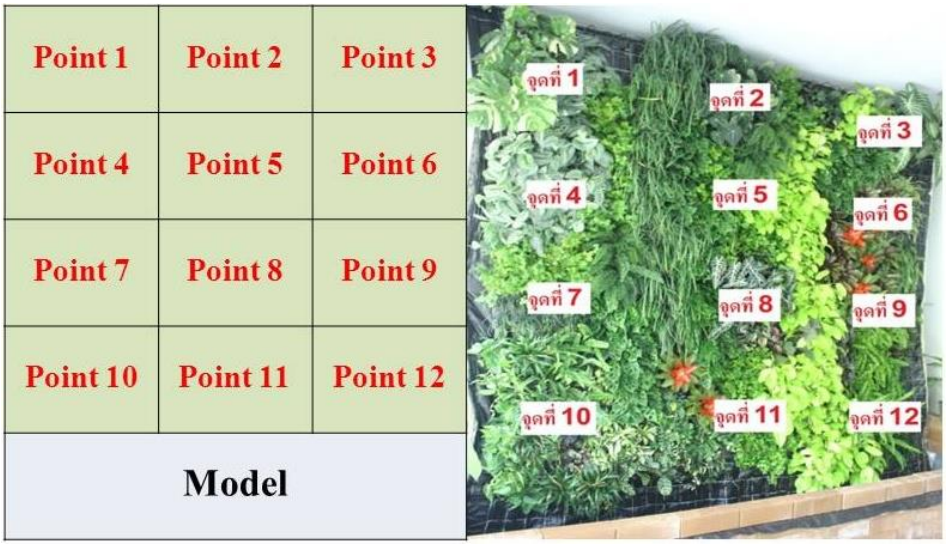

Figure 1. Points of light intensity

Survival rates

For survival rates showed that all species gave different survival rates as 100%, 60%, 40%, 20% and 0% or died. There were 12 species that had survival rates percentages as 100%, they were *Monstera delicosa*, *Scindapsus pictus*, *Philodendron cordatum*, *Anthurium crystallinum*, *Dracaena surculosa*, *Philodendron erubescens*, *Monstera karsteniana*, *Alocasia sanderiana*, *Ophiopogon jaburan*, *Ophiopgon japonicas*, *Syngonium podophyllum* and *Cercestis mirabilis.*

Three species gave survival rates percentages as 80%, there were *Caladium lindenii*, *Syngonium podophyllum* and *Philodendron moonlight*, while *Monstera oblique*, *Philodendron moonshine*, *Pseudorhipsalis ramulosa* and *Philodendron Imperial* gave survival rates as 60%. *Nephrolepsis biserrata* was the species which gave survival rates as 40%. Three species were gave survival rates as 20%, there were *Neoregelia carolinae*, *Asplenium thunbergii* and *Anthurium andraeanum*. Finally, there were 9 species which not appropriate for this garden that they all died or gave survival rates as 0%, there were *Selaginella wallichii*, *Geogenanthus undatus*, *Peperomia caperata*, *Echinodosus cordifolius*, *Phyllanthus myrtifolius*, *Chlorophytum bichetii*, *Nephrolepis exaltata*, *Aeschynanthus radicans* and *Calathea makoyana*.

Growth rates

The result of growth rates showed different scores. Six species gave 5 scores of growth rates, there were *Philodendron erubescens*, *Scindapsus pictus*, *Anthurium crystallinum*, *Monstera delicosa*, *Philodendron cordatum* and *Monstera karsteniana*, while 8 species gave four scores, *Cercestis mirabilis*, *Caladium lindenii*, *Philodendron moonlight*, *Philodendron moonshine*, *Philodendron Imperial*, *Syngonium podophyllum*, *Alocasia sanderiana* and *Dracaena surculosa.*

The species gave 3 scores of growth rates had 5 species, there were *Monstera oblique*, *Pseudorhipsalis ramulosa*, *Asplenium thunbergii*, *Nephrolepsis biserrata* and *Neoregelia carolinae.* Four species got 2 scores; they were *Anthurium andraeanum*, *Ophiopogon jaburan*, *Ophiopgon japonicas* and *Syngonium podophyllum*.

Unfortunately, 9 of 32 species got 1 or 0 scores that's mean they couldn't survive in this garden; they were *Echinodosus cordifolius*, *Phyllanthus myrtifolius*, *Chlorophytum bichetii*, *Nephrolepis exaltata*, *Aeschynanthus radicans*, *Selaginella wallichii*, *Selaginella wallichii*, *Geogenanthus undatus* and *Peperomia caperata* (Tabel 1).

Beautifulness rates

After collected the data, all species gave beautifulness differently and got different score levels. Five species got full scores which was 5 scores, they were *Philodendron erubescens*, *Scindapsus pictus*, *Philodendron moonlight*, *Philodendron cordatum* and *Monstera karsteniana*, while another 10 species got 4 scores, *Alocasia sanderiana*, *Cercestis mirabilis*, *Anthurium crystallinum*, *Dracaena surculosa*, *Monstera delicosa*, *Caladium lindenii*, *Philodendron moonshine*, *Philodendron Imperial*, *Nephrolepsis biserrata* and *Syngonium podophyllum*.

Three scores was belong to 5 species of plants, there were *Asplenium thunbergii*, *Monstera oblique*, *Neoregelia carolinae*, *Pseudorhipsalis ramulosa* and *Syngonium podophyllum* while 4 species got 2 scores, there were *Anthurium andraeanum*, *Ophiopogon jaburan*, *Ophiopgon japonicas* and *Syngonium podophyllum*. And 9 species had died; they were *Echinodosus cordifolius*, *Phyllanthus myrtifolius*, *Chlorophytum bichetii*, *Nephrolepis exaltata*, *Aeschynanthus radicans*, *Selaginella wallichii*, *Peperomia caperata*, *Geogenanthus undatus* and *Calathea makoyana* (Table 2).

Table 1. Showed growth rates of 12 species plant

No.	Plant species	Growth rates								Average
		1st month	2nd months	3rd months	4th months	5th months	6th months	7th months	8th months	
1	*Asplenium thunbergii*	4.80	4.40	4.10	3.70	3.00	2.30	2.10	1.20	**3.20**
2	*Alocasia sanderiana*	4.80	4.50	4.70	4.80	4.80	3.80	5.00	4.40	**4.60**
3	*Monstera obliqua*	4.50	4.25	3.53	3.60	3.70	3.30	3.62	3.00	**3.69**
4	*Philodendron erubescens*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
5	*Echinodosus cordifolius*	0.00	0.00	4.05	4.40	2.90	3.90	died	died	**died**
6	*Phyllanthus myrtifolius*	died	died	died	died	died	died	died	died	**died**
7	*Chlorophytum bichetii*	died	died	died	died	died	died	died	died	**died**
8	*Scindapsus pictus*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
9	*Cercestis mirabilis*	4.60	4.30	4.50	4.30	3.50	3.90	5.00	4.20	**4.29**
10	*Anthurium crystallinum*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
11	*Dracaena surculosa*	4.10	4.60	4.90	4.65	4.40	5.00	5.00	4.20	**4.61**
12	*Monstera delicosa*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
13	*Caladium lindenii*	4.90	4.70	4.80	4.90	4.70	5.00	5.00	5.00	**4.88**
14	*Philodendron moonlight*	4.92	5.00	4.65	4.90	4.80	5.00	5.00	5.00	**4.91**
15	*Philodendron cordatum*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**

Table 1(Continued)

16	*Philodendron moonshine*	5.00	4.20	4.70	5.00	4.80	5.00	4.30	4.20	**4.65**
17	*Philodendron Imperial*	4.60	5.00	4.90	4.80	5.00	4.40	4.30	4.00	**4.63**
18	*Neoregelia carolinae*	3.70	4.20	4.80	4.00	4.00	1.80	2.90	1.90	**3.41**
19	*Anthurium andraeanum*	3.80	3.70	3.90	4.20	3.30	1.50	2.00	1.00	**2.93**
20	*Nephrolepsis biserrata*	2.90	3.20	4.00	3.80	5.00	4.20	3.20	3.90	**3.78**
21	*Nephrolepis exaltata*	died	died	died	died	died	died	died	died	**died**
22	*Aeschynanthus radicans*	died	died	died	died	died	died	died	died	**died**
23	*Selaginella wallichii*	1.90	2.00	3.90	3.00	3.00	1.50	1.50	died	**died**
24	*Peperomia caperata*	died	died	died	died	died	died	died	died	**died**
25	*Ophiopogon jaburan*	3.50	3.20	2.90	3.20	3.00	2.10	2.00	1.90	**2.73**
26	*Ophiopgon japonicas*	3.00	2.00	2.56	2.22	2.30	2.00	1.50	1.20	**2.10**
27	*Geogenanthus undatus*	5.00	4.50	4.90	4.50	3.50	1.50	1.50	died	**died**
28	*Pseudorhipsalis ramulosa*	3.20	3.60	4.20	3.90	4.10	5.00	4.00	2.80	**3.85**
29	*Syngonium podophyllum*	5.00	4.80	4.90	4.45	5.00	5.00	5.00	4.90	**4.88**
30	*Calathea makoyana*	died	died	died	died	died	died	died	died	**died**
31	*Monstera karsteniana*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
32	*Syngonium podophyllum*	4.90	4.30	3.40	3.10	2.70	1.30	1.50	1.20	**2.80**

Table 2. Showed beauty rates of 12 species plants

No.	Plant species	Beauty rates								Average
		1st month	2nd months	3rd months	4th months	5th months	6th months	7th months	8th months	
1	*Asplenium thunbergii*	4.70	4.10	3.80	3.50	3.10	2.30	2.90	1.70	**3.26**
2	*Alocasia sanderiana*	4.90	4.70	4.60	4.30	4.50	2.40	5.00	4.90	**4.41**
3	*Monstera obliqua*	4.40	3.50	3.90	3.60	4.20	2.80	1.90	1.50	**3.23**
4	*Philodendron erubescens*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
5	*Echinodosus cordifolius*	0.00	0.00	4.80	4.00	2.10	1.70	1.70	died	**died**
6	*Phyllanthus myrtifolius*	died	died	died	died	died	died	died	died	**died**
7	*Chlorophytum bichetii*	died	died	died	died	died	died	died	died	**died**
8	*Scindapsus pictus*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
9	*Cercestis mirabilis*	4.40	4.80	3.50	4.70	3.70	3.80	5.00	4.90	**4.35**
10	*Anthurium crystallinum*	5.00	4.80	4.80	5.00	4.90	4.90	5.00	5.00	**4.93**
11	*Dracaena surculosa*	4.50	4.70	4.80	5.00	5.00	5.00	5.00	5.00	**4.88**
12	*Monstera delicosa*	4.80	4.90	4.80	5.00	4.70	5.00	5.00	5.00	**4.90**
13	*Caladium lindenii*	4.80	4.70	4.80	4.70	4.60	4.60	5.00	4.80	**4.75**
14	*Philodendron moonlight*	0.00	5.00	5.00	5.00	5.00	5.00	5.00	4.90	**4.36**
15	*Philodendron cordatum*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
16	*Philodendron moonshine*	5.00	4.50	5.00	5.00	5.00	4.80	5.00	4.20	**4.81**
17	*Philodendron Imperial*	0.00	5.00	5.00	5.00	4.90	4.40	5.00	4.40	**4.21**
18	*Neoregelia carolinae*	4.20	4.40	4.70	5.00	4.50	3.40	2.40	3.30	**3.99**
19	*Anthurium andraeanum*	4.60	4.10	3.70	5.00	2.60	1.50	1.80	1.00	**3.04**
20	*Nephrolepsis biserrata*	3.20	3.20	4.00	4.00	4.70	1.90	5.00	5.00	**3.88**
21	*Nephrolepis exaltata*	died	died	died	died	died	died	died	died	**died**
22	*Aeschynanthus radicans*	died	died	died	died	died	died	died	died	**died**
23	*Selaginella wallichii*	2.50	2.40	3.20	3.20	2.80	1.40	1.60	died	**died**

Table 2. (Continued)

No.	Plant species	Beauty rates								*Average*
		1st month	**2nd months**	**3rd months**	**4th months**	**5th months**	**6th months**	**7th months**	**8th months**	
24	*Peperomia caperata*	died	died	died	died	died	died	died	died	**died**
25	*Ophiopogon jaburan*	3.10	3.00	2.80	2.80	2.10	1.70	2.50	1.70	**2.46**
26	*Ophiopgon japonicas*	2.50	1.90	2.10	2.10	2.50	1.70	1.90	1.30	**2.00**
27	*Geogenanthus undatus*	5.00	4.90	4.80	3.80	2.80	1.90	2.00	died	**died**
28	*Pseudorhipsalis ramulosa*	3.30	3.70	4.00	4.10	3.60	3.20	3.30	2.20	**3.43**
29	*Syngonium podophyllum*	4.70	4.70	4.70	4.90	5.00	4.80	5.00	5.00	**4.85**
30	*Calathea makoyana*	died	died	died	died	died	died	died	died	**died**
31	*Monstera karsteniana*	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
32	*Syngonium podophyllum*	5.00	4.30	3.30	3.20	2.90	1.50	1.40	1.50	**2.89**

Discussion

All plant species gave different results where the species that passed the criterion had been gave survival rates more than 80% and the beautifulness rates and growth rates must be more than 4 scores. Three species got 80% of survival rates which were *Caladium lindenii*, *Syngonium podophyllum* and *Philodendron moonlight*, while 12 species gave survival rates 100%, they were *Monstera delicosa*, *Scindapsus pictus*, *Philodendron cordatum*, *Anthurium crystallinum*, *Dracaena surculosa*, *Philodendron erubescens*, *Monstera karsteniana*, *Alocasia sanderiana*, *Ophiopogon jaburan*, *Ophiopgon japonicas*, *Syngonium podophyllum* and *Cercestis mirabilis.*

Growth rates showed that 8 species of plant got 4 scores of growth rates, there were *Cercestis mirabilis*, *Caladium lindenii*, *Philodendron moonlight*, *Philodendron moonshine*, *Philodendron Imperial*, *Syngonium podophyllum*, *Alocasia sanderiana* and *Dracaena surculosa*, while 6 species of plants got 5 scores, they were *Philodendron erubescens*, *Scindapsus pictus*, *Anthurium crystallinum*, *Monstera delicosa*, *Philodendron cordatum* and *Monstera karsteniana*.

Ten species of plants gave 4 scores of beautifulness rates, there were *Alocasia sanderiana*, *Cercestis mirabilis*, *Anthurium crystallinum*, *Dracaena surculosa*, *Monstera delicosa*, *Caladium lindenii*, *Philodendron moonshine*, *Philodendron Imperial*, *Nephrolepsis biserrata* and *Syngonium*

podophyllum, while 5 species got full scores which was 5 scores, they were *Philodendron erubescens*, *Scindapsus pictus*, *Philodendron moonlight*, *Philodendron cordatum* and *Monstera karsteniana*.

It can concluded that there were 12 species of plant which passed the criterion, 80% survival rates and 4 scores both growth and beautifulness rates. They were *Caladium lindenii*, *Philodendron moonlight*, *Syngonium podophyllum*, *Alocasia sanderiana*, *Philodendron erubescens*, *Scindapsus pictus*, *Cercestis mirabilis*, *Anthurium crystallinum*, *Dracaena surculosa*, *Monstera delicosa*, *Philodendron cordatum* and *Monstera karsteniana*.

This result indicated that light intensity was the main factor which influence for many plants which grown in vertical garden. Different species of plant required different light intensity; some species required directed light such as Rosa sp. and *Helianthus annuus*, but some species required dimly light or didn't required directed light (Joanna, 2009). Mostly, indoor plant had fragile leaf that couldn't endure to high intensity light, and they would grow better in dimly light with high moisture with calm wind (Xenia. 2009). However all plants which used in this study were all indoor plants but they were required different level of light intensity and all 12 points got different level of light intensity during 500LUX – 2,000LUX. Five species was suitable for growth on 1,7000LUX – 2,000LUX which were *Monstera delicosa*, *Scindapsus pictus*, *Anthurium crystallinum*, *Caladium lindenii* and *Philodendron erubescens.* Another way, vertical garden had depend on the botany of plant where some species required low light intensity which was 500LUX had 5 species, there were *Dracaena surculosa*, *Philodendron erubescens*, *Monstera karsteniana***,** *Cercestis mirabilis* and *Syngonium podophyllum***.** Nutrient solution and EC value was also important for plants. The EC value was suitable with ornamental plant was 0.8-3.0mS/cm (Developmental Club of Ornamental Plant, 2004). In the first month the EC value was 1.2mS/cm which most appropriated for *Selaginella wallichii*, *Ophiopogon jaburan* and *Ophiopgon japonicas* but it was not suitable all species. *Selaginella wallichii* had withered and blight leaf whole trunk while *Ophiopogon jaburan* and *Ophiopgon japonicas* had withered on tip, so had to reduce EC value as 0.8 mS/cm for reduce the blight leaf and withered leaf of some species.

Beside this, there were fraction of media blocked the tube for distributed nutrient that made the plant got nutrient deficiency and became withered also.

Conclusion

Twelve species of indoor ornamental plant which growing in vertical garden in different light intensity between 500LUX-2,000LUX and the concentration of solution was 0.8mS/cm, would screened species which gave survival rates more than 80%, beautifulness and growth rates more

than 4 scores. They were *Caladium lindenii*, *Philodendron moonlight*, *Syngonium podophyllum*, *Alocasia sanderiana*, *Philodendron erubescens*, *Scindapsus pictus*, *Cercestis mirabilis*, *Anthurium crystallinum*, *Dracaena surculosa*, *Monstera delicosa*, *Philodendron cordatum* and *Monstera karsteniana*.

It is suggested that light intensity and concentration of nutrient solution are very important for plants. In the next study we suggest that should study about the light intensity and concentration of nutrient solution for each species.

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